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Methods of Improving the Mississippi River

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METHODS OF IMPROVING THE MISSISSIPPI RIVER

BY

FORREST C McNARY

THESIS

FOR THE

DEGREE OF BACHELOR OF SCIENCE

IN

CIVIL ENGINEERING

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May 24, 1912

This is to certify that the thesis of FORREST C MCNARY entitled METHODS OF IMPROVING THE MISSISSIPPI RIVER was prepared under my personal supervision; and I recommend that it be approved as meeting this part of the requirements for the degree of Bachelor of Science in Civil Engineering.

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INTRODUCTION.

The Mississippi River, on account of its great size and the richness of the vast area which it drains, is the most important of all the rivers of the United States. It rises in a small lake in Minnesota and flows southward to the Gulf of Mexico, draining nearly all of the land between the Alleghany and the Rocky Mountains, which comprises an area of about one million, two hundred and forty-four thousand square miles, or two-fifths of the United States. Its largest tributaries are the Missouri and the Ohio Rivers, after which come the Illinois, the Tennessee, the Arkansas, the Cumberland, and the Red Rivers, all of which are navigable streams.

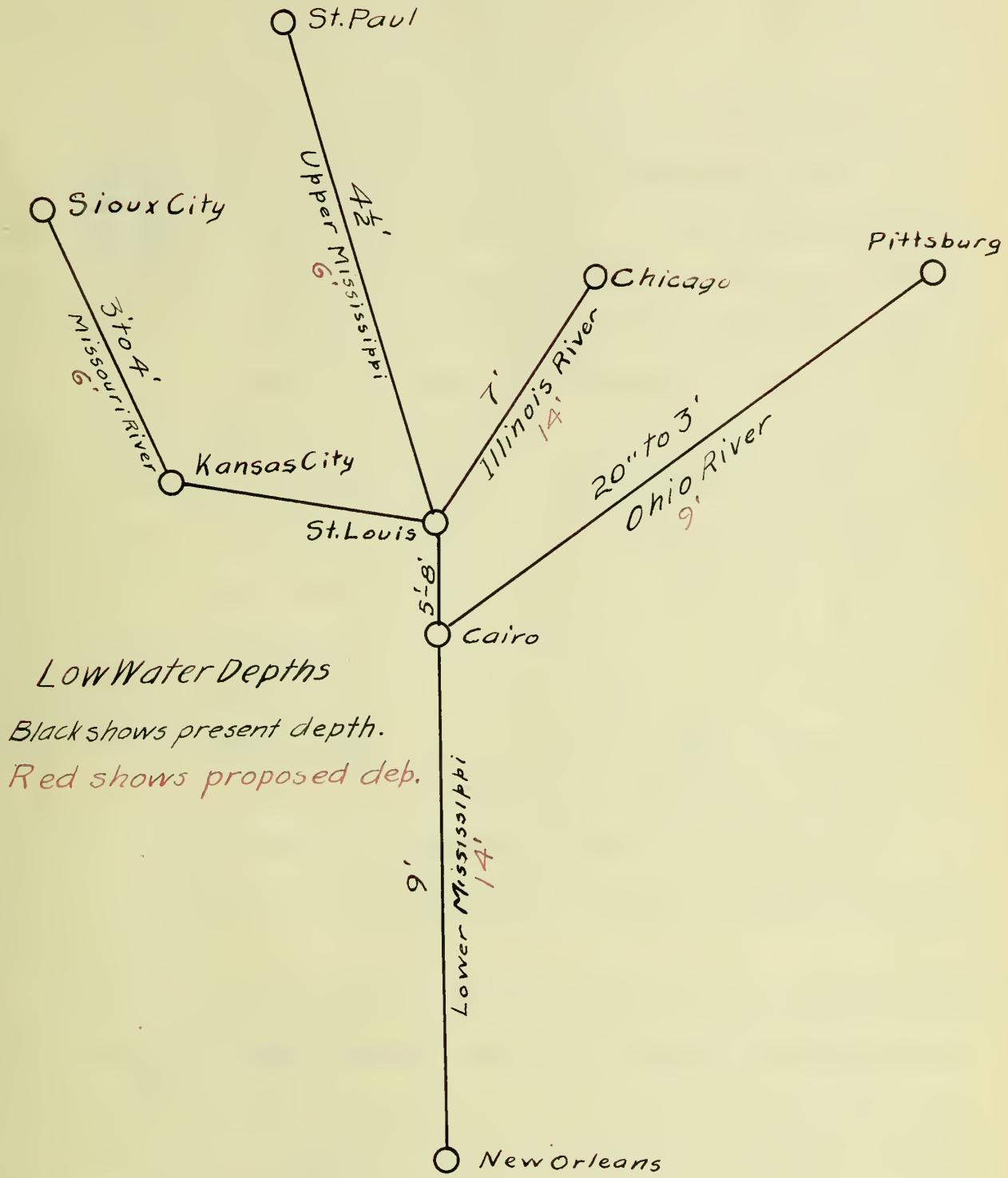
The first two hundred miles of the stream extends from Lake Itasca to Pokegama Falls, Minnesota. The drainage area of this portion of the river is thickly dotted with small lakes, and the elevated portions of the country are heavily wooded. It is here that the reservoirs for the regulation of the flow in the river have been built.

From Pokegama Falls to the Missouri River, the stream flows through narrow and stable banks and is interrupted by numerous falls, rapids and islands. Some of these falls furnish water power and practically all of them have been improved by canals or locks.

The Missouri empties a great flood of very muddy water into the stream and from its point of entrance to the Ohio the bank erosion is much more noticeable. Below the Ohio the stream bed seems to be composed entirely of alluvial deposits, and it is here that the Government has spent most of its effort in trying to

keep the stream in a fairly stable condition. It has been necessary to build false banks which can not be eroded and to construct earthen ramparts to keep back the floods. In addition it has been found necessary to keep a number of dredge boats at work cutting away the shoals which block the channel at the bends.

It is the object of this paper to describe briefly the character and extent of the work which has been done on the Mississippi to improve it for the purposes of navigation and for the protection of the property interests along its course.



The Mississippi and Its Principal Tributaries

Fig. 1

CHAPTER I.

THE JETTIES.

The building of the jetties at the mouth of the Mississippi River is probably the most important engineering work which has ever been attempted in the interests of river navigation, as it opens to commerce one of the greatest water-ways in the world and furnishes an exit for the products of the entire Mississippi Valley, which had previously been sent overland at great expense. It may seem strange that a great river like the Mississippi could not furnish a passage-way for trade vessels wishing to enter or to leave it, when it is known to have a depth of two hundred feet in places, but such was the case before 1879. The river had shoaled up at its mouth to such an extent that even small ocean steamers were unable to enter, and ten feet of water was all that could be depended upon. Now, however, after the removal of seven million cubic yards of sand, mud, and clay, a depth of more than thirty feet is constantly maintained over a width of nearly two hundred feet and the largest steamers dock at the New Orleans wharves.

The work is of interest to engineers because of the stupendous difficulties that were encountered in its construction and, before going farther, it will be well to describe briefly the conditions which existed at the mouth of the river before the jetties were commenced.

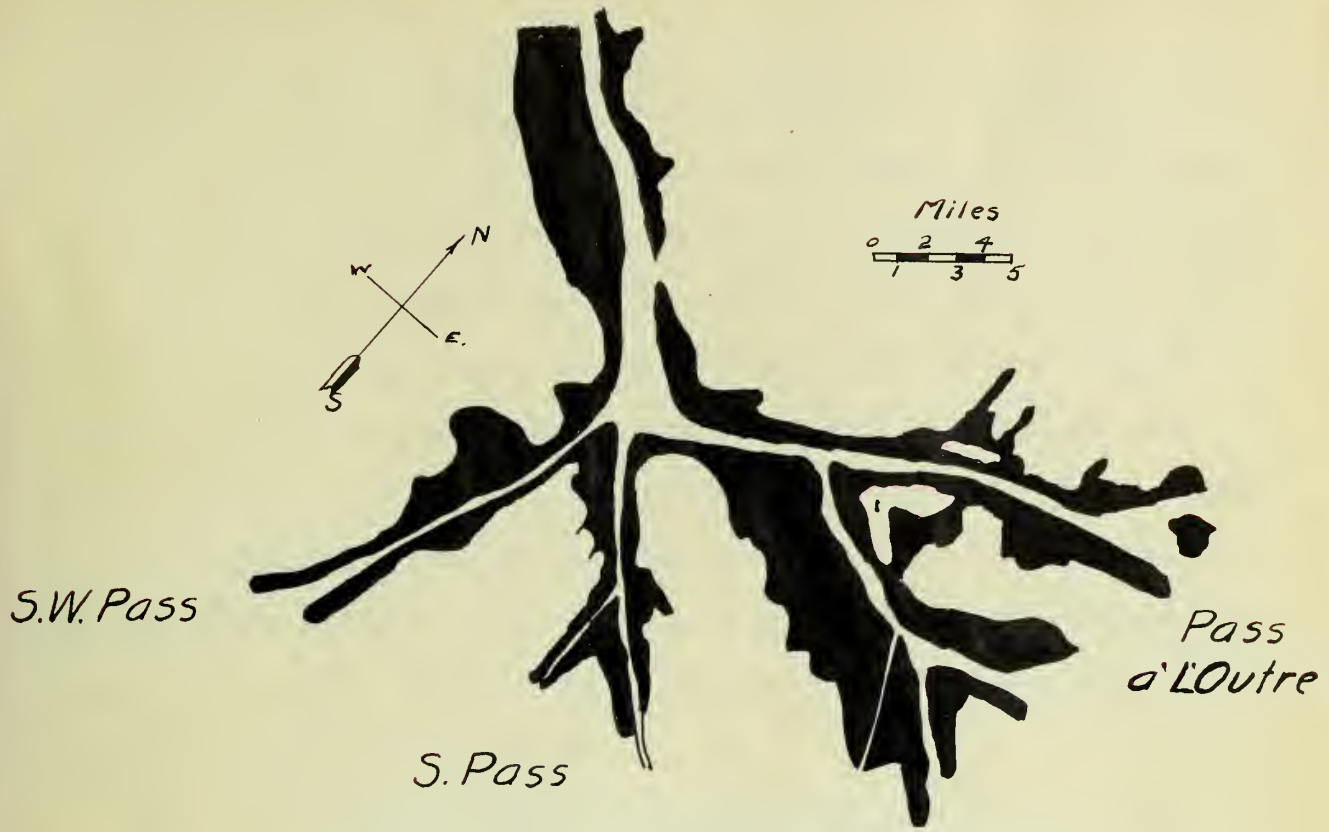
The river discharges an average of about five hundred thousand cubic feet per second. At New Orleans the depth is more than one hundred and fifty feet and the width is half a mile.

This deep channel extends to within fifteen miles of the Gulf, where it gradually widens to one and three-quarters miles, and decreases in depth to thirty feet. Here it branches into three outlets known as the Passes (see Fig.2) between which are wide shallow embayments. The widening of the river causes a loss of velocity and the water begins to drop its sediment, which causes shoaling. When the mouths of the passes are reached the water spreads out in a full half-circle and it is here that the heaviest shoaling takes place.

The three passes are known as Pass a l'Outre, Southwest Pass and South Pass. South Pass is more nearly in line with the course of the river than either of the other two, and this is the one in which the jetties were built. It is the smallest of the three and discharges only one-tenth of the volume of the river. It must be kept in mind that these passes are cut in the sand and the mud which havebeen brought down the river, and consequently no great amount of solidity can be expected, especially when the fact is considered that the three passes are nearly always one continuous sheet of water.

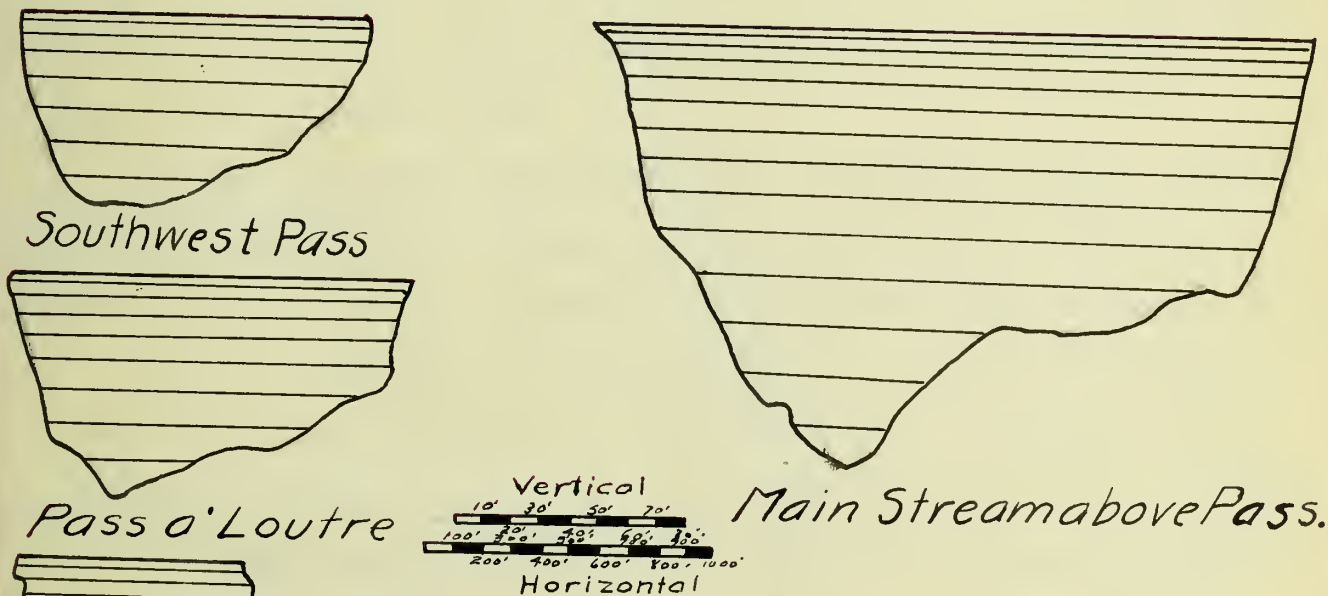
The plan of the jetties was to so confine the volume of water leaving South Pass that the increase in the velocity would cause the water to pick up the particles which had been dropped and to transport them to the Gulf. In doing this it became necessary to build dikes across the two other passes in order to force the water to enter South Pass, and it is here that the greater part of the work took place.

The success of the jetties was due almost entirely to the



The Mississippi Delta

Fig. 2



Sections showing Relative Sizes of Passes & Stream

untiring efforts of James B. Eads who received a contract for their construction in March, 1875. His original bid of eleven million dollars was on the Southwest Pass, but the Senate amended the bill for the appropriation to apply to the South Pass. The amended bill called for a channel thirty feet deep and three hundred and fifty feet wide to be built and maintained for twenty years at a cost of $5,250,000 when the work was completed, and $100,000 annually for twenty years. In 1879 the bill was amended, reducing the required dimensions of the channel to twenty six feet in depth over a width of two hundred feet, with a central depth of thirty feet.

The considerations which determined the location of the jetties were:

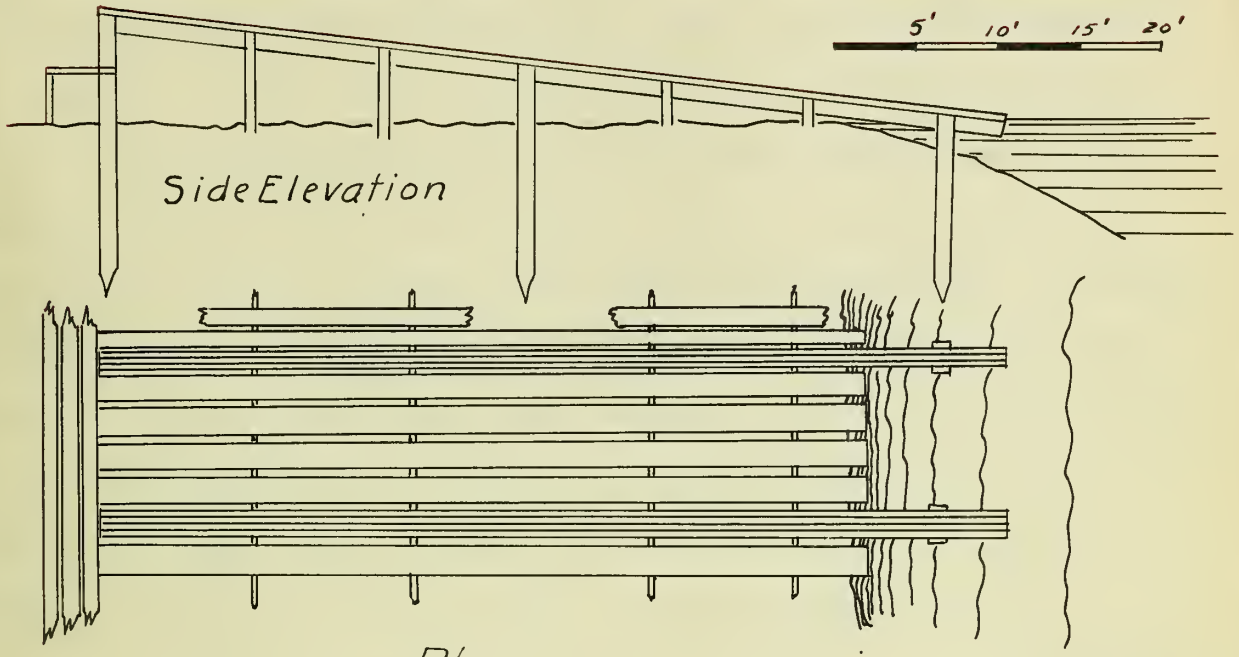
First. To locate them at such a distance apart as would make them secure against any subsidence of the ground upon which they were resting, which might be induced by the excavation of a deep channel between them.

Second. To direct the discharge into the Gulf across and not against the littoral currents, as such a step would tend to retard the flow and to accelerate the dropping of the sediment.

Third. To enclose the natural channel within the jetties, leaving the shoalest waters on each side of it in which to construct the jetties.

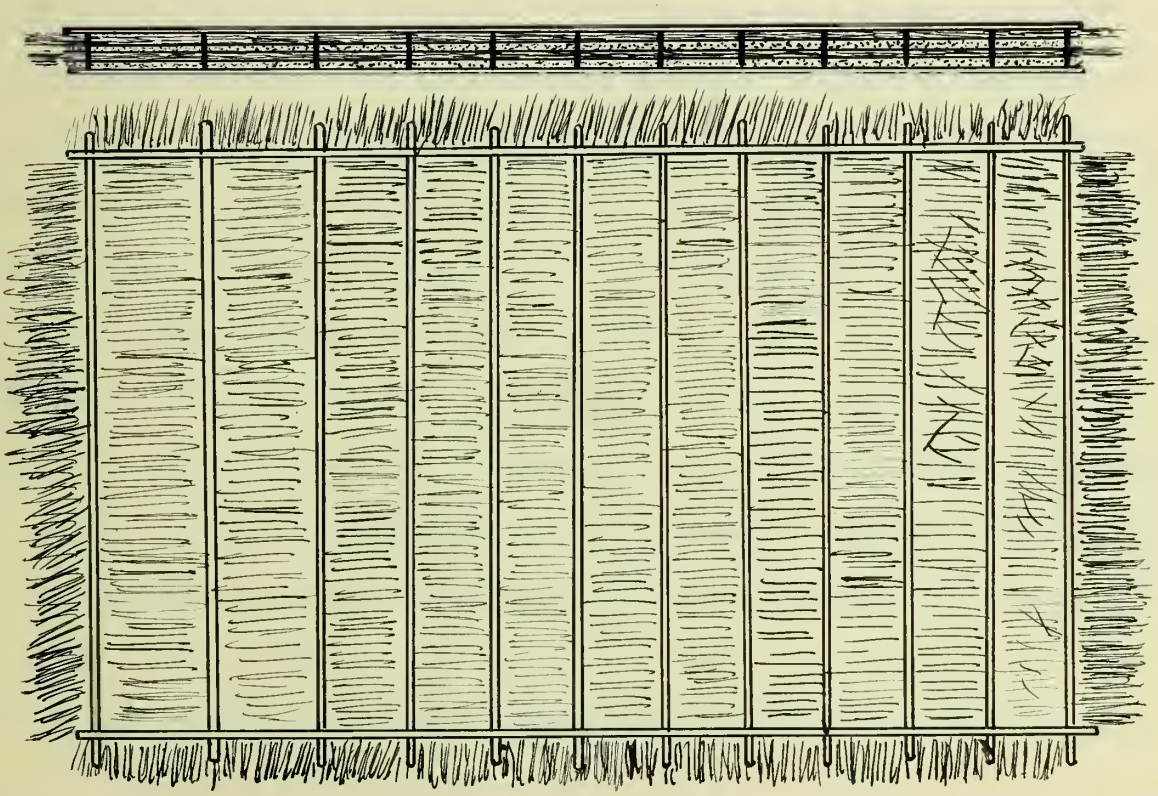
Work was commenced on the east jetty which extended south and east from the end of the land, and followed the general direction of the channel for twelve thousand one hundred feet. The alignment was established by a line of piling, the first

mile of which consisted of two rows twelve feet apart, the piles being spaced eight feet apart in each row, and the remaining distance of six thousand eight hundred and twenty feet consisted of one row, the piles being ten to twenty feet apart. These piles were intended for guides for placing the willow mattresses which formed the bulk of the jetties. While the piles were being driven, mattresses were made from the great growth of willows found on the delta. Inclined ways were first built (as shown in Fig. 3) and upon these were placed yellow pine strips 6 inches wide by 2 1/2 inches thick and from twenty to forty feet in length. The strips were laid parallel to each other and five feet apart crosswise of the ways. They were thus joined together at their ends so as to be one hundred feet long, and one and one-eighth inch holes were bored within every five feet. Round hickory pins, 2 feet between shoulders, with the ends turned to fit the holes, were driven into the strips and fastened in with nails and wedges. Willows from fifteen to thirty feet long and varying in diameter from one-half to two and one-half inches at the butt were piled in alternate layers at right angles to each other until the tops of the pins were entirely covered. The willows were then forced down and a set of strips corresponding to those used on the bottom were put on at right angles to the first set. This made a mattress one hundred feet long, forty feet wide and two feet thick. The mattress was then pulled from the ways by a steamboat and towed to the piling. Upon reaching the piling the mattress was floated around close against it with the larger axis parallel to the current. Stone



Mattress Ways and Mattress

Fig. 3



was thrown upon the outer edge of the mattress and as it sank the current flowing seaward through the piles floated stone barges in over this sunken edge so that stone could be thrown on the middle and the inner edge until the mattress sank close to the piling. This process was continued over the entire length of the piling, making a carpet which prevented deepening, and narrower mattresses were placed upon the first layer until the last mattress extended above the water, making a porous dam thirty to fifty feet wide at the bottom and twenty to twenty-five feet wide at the top. This greatly retarded the flow through the piling, causing a greater volume to flow in the channel.

The distances along the piling were noted in 100-foot stations, the zero station being at land's end on the east jetty. Every fifth guide pile was numbered and marked, and its distance from zero noted. The locations of the mattresses were plotted on a profile by noting their position with respect to these piles.

As soon as the east jetty was finished work was started on the west jetty. The guide piling for this jetty was commenced opposite and one thousand feet west of station forty plus fifty-eight on the east jetty, and it extended seaward parallel to it. It was constructed in a manner similar to the east jetty, except that less piling was used and the mattresses were laid on both sides of the piling with a plank apron placed vertically against the piling to secure greater imperviousness. The average width at the bottom and top was thirty-five and twenty-five feet, respectively, and the average depth of water was eight feet.

At the same time a five-hundred-and-fifty-foot dam called

"Kipp Dam" was built which connected the end of the jetty with the land on the west. The depth of water gradually increased to eighteen feet at the west jetty. A row of piles eighteen feet apart were driven and a waling strake of six inches by twelve inches was bolted to them. Foundation mattresses sixty feet wide and two feet thick were sunk above them, and wooden aprons sixty feet in length were placed vertically against the piles with the lower edge resting on the mattresses. The aprons were floated into position, as were the mattresses, and the inner edge was raised by a pile driver. This allowed the current to force the apron firmly against the piling, after which it was forced down by levers and pile-driver hammers until it rested firmly upon the mattresses. Piles were then driven on the up-stream side of it and bolted to the guide piles, thus holding it firmly in place. A second course of mattresses, thirty-two feet wide and two feet thick, was then laid horizontally on the up-stream side of the aprons and against them. The aprons along the entire length of the dam were put in place in one day.

Although the river was very low, this sudden obstruction of the current produced a head of water above the dam which at ebb tide was between seven and eight inches. This forced a strong current through the opening between the lower edge of the aprons and the mattresses which excavated deep holes below the dam where no protecting mattresses had been placed, producing an average deepening of eight to ten feet along the entire dam. At one point fifty feet of piling was washed out and an apron carried away. A second row of piles was driven eight feet apart and

ten feet above the old row. The dam was then built to the surface as rapidly as possible and the holes gradually filled up with sediment.

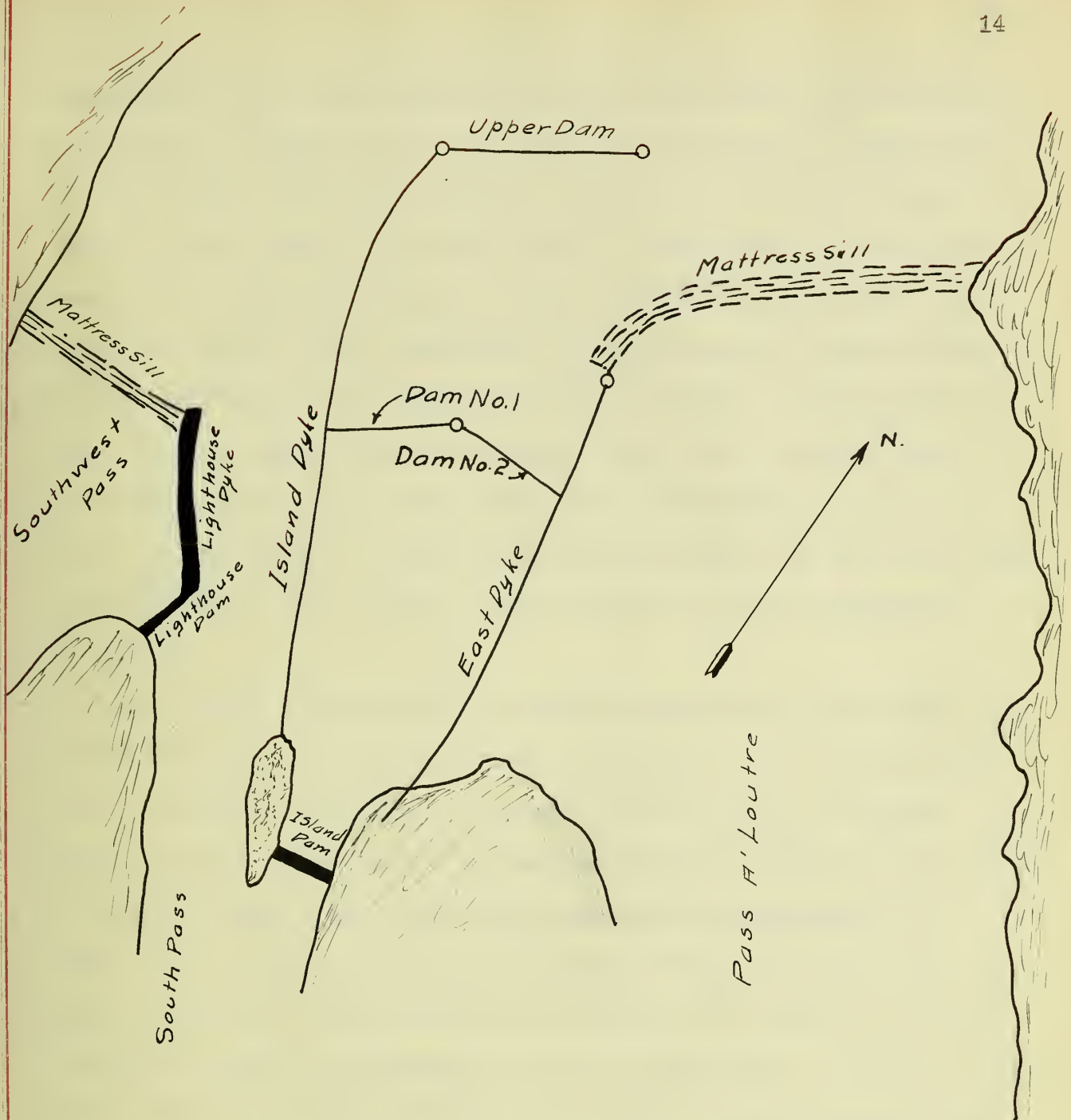
The exposed parts of the jetties were now more thoroughly covered with rock, and wing-dams or spurs were built in pairs - one on each jetty and at right angles to it - and extended from station ninety to station one hundred and eighteen where the least amount of scour had taken place. In constructing these wings a line of guide piles was driven from the jetty about one hundred and fifty feet toward the channel. Foundation mattresses were sunk between the piles connecting with the foundation mattresses of the jetties and extending fifty feet beyond the end of the proposed dam. A second row of piles was driven through them twelve feet from the lower edge and eight feet apart, and a waling strake was bolted to the lower side of the piles two feet above average flood-tide. Mattresses seventy-five feet long and two feet thick were placed vertically against the piles, as were the aprons in the Kipp dam. These wing-dams were intended to force the current into the channel and hence to deepen it. They accomplished gratifying results.

At this time (about one year after the work was commenced), the jetties were simply walls of uncompressed willows, but they affected important results, causing the current to cut the shoal between the two and one-third miles of jetties to such an extent that on the 4th of March, 1876, the schooner Mattie Atwood, drawing thirteen and a half feet of water, passed through the new channel.

The problem of getting the water into South Pass proved to be a much more difficult problem than the narrowing of the channel at its mouth. At the head of the passes the river was about two miles wide and South Pass was fifteen hundred feet wide and fourteen feet deep at that time.

As an initial step the dike marked east dike was constructed. It began at the point of land between South Pass and the Pass a l'Outre and extended northward, curving to the west with a radius of eight thousand feet, and ended in twenty-four feet of water, six hundred feet east of the middle of the river and thirty-two hundred and fifty feet from the starting point. It was constructed in very much the same manner as Kipp dam and was intended to deflect part of the water flowing into Pass a l'Outre into South Pass so as to produce a channel east of the island shown in Fig. 4

About the same time a dam was built on the western side of the channel about half way between the head and the mouth of the pass where a lake known as Grand Bayou discharged a stream about three feet deep and two hundred and seventy-five feet wide. This leak was closed by a dam consisting of four rows of piles, two rows of vertical mattresses, and one row of horizontal mattresses, adding about 33% to the total flow reaching the mouth of the pass. In order to avoid being without a channel suitable for large steamers while perfecting the channel on the east side of the island by closing that on the west, East Dyke which had been erected at a cost of $180,000 was abandoned. The east channel was then closed by Island Dam, and Island Dyke 3400 feet long was constructed from the upper end of the island nearly parallel to



Works at Head of Passes.

Fig. 4

East Dyke, and a spur 1700 feet long called Upper Dam was built into Pass a l'Outre in a north-easterly direction. Light House Dyke and Dams number One and Two were built for the same purpose. It was found, however, that the reduction of the cross-sections of Southwest Pass and Pass a l'Outre was quickly overcome by a proportional deepening of the channels, and mattress sills beginning at the ends of the Light House and East Dykes were built entirely across Southwest Pass and Pass a l'Outre as shown. These sills were about eight feet high and were composed of mattresses 40 feet long, 30 feet wide and two feet thick, heavily loaded with stone. They caused a marked retardation of the flow.

The shoals at both the head and the mouth of the passes was now found to be rapidly scouring and Captain Eads devoted his time to putting wing dams along the jetties and to dredging shallow spots with a newly patented hydraulic dredge which sucked up the mud with large centrifugal pumps, and deposited it in tanks. His object was to get a channel twenty-two feet deep and nine hundred feet wide as soon as possible in order to receive the first payment of $500,000 from the government. This he succeeded in doing in January, 1878, and in 1879 he was paid the entire amount for the channel which was two hundred feet wide and twenty-six feet deep, and had a central depth of thirty feet.

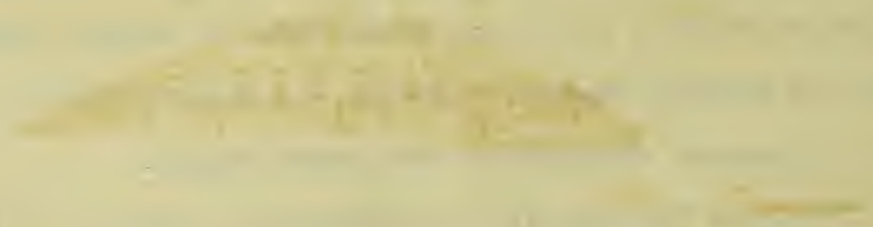
In 1878-9 the sea ends of the jetties were protected by palmetto cribbing filled with rock. This was capped by a concrete block twelve feet wide at the base and shaped as shown in Fig. 5. Spur-dykes were built along the extreme ends about one

hundred feet apart to prevent "racers" caused by the breaking up of the waves upon striking the cribbing.

A channel thirty feet deep over a width of twenty feet, and twenty-six feet deep over a width of two hundred feet was generally maintained by Captain Eads until his contract expired January 28, 1901. During this time he had kept the jetties in repair and had built an interior jetty, six thousand eight hundred and ten feet long, two hundred feet inside East Jetty, thus narrowing the waterway to six hundred and thirty feet. He had also built some new wing-dams and had dredged more or less each year except from 1883 to 1888. The area just outside the jetties filled about eight feet in the first four years after which it scoured to some extent, and has since changed very little.

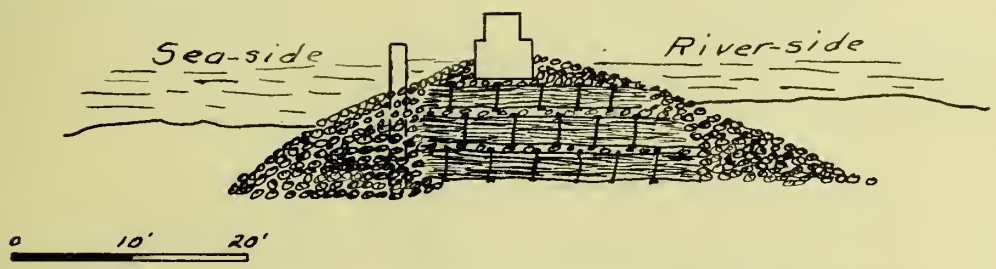
After Captain Eads' contract expired the government raised the sills across Southwest Pass and Pass a l'Outre and endeavored with a fair degree of success to cut the thirty-foot channel to thirty-five feet by means of dredges. The vessels, however, increased to such a size during the twenty-five years following the opening of the passes that the ones of the greatest carrying capacity and the lowest freight rates were shut out of the river by the lack of water over the bars. A great many delegations appeared before the House Committee on Rivers appealing for a new and deeper channel through the Southwest Pass, and on June 19, 1902 Congress authorized the improvement.

The new jetties in the Southwest Pass are a great deal larger than the ones in the South Pass, but were constructed on the same general principles. They consist of two parallel walls



about a half mile apart and four miles long. They were constructed in much the same manner as the south jetties and were capped with a concrete capping twelve feet wide at the bottom, eight and one-half feet wide at the top and four and one-half feet thick. The foundation mattresses are from three to four times the width of those in the old jetties, or about one hundred and fifty feet. This increased width is for the purpose of preventing scour. It is confidently expected that the bottom tiers of mattresses will sink into the mud in a few years on account of the great weight of the rock ballast and the capping, and will become as strong as the natural banks of the river. The work on these jetties was completed in 1908, and they have proven a great success. The minimum depth of water is thirty-five feet and the width one thousand feet.

It is safe to state that the jetties are the most successful improvement which has yet been attempted in the interests of river commerce.



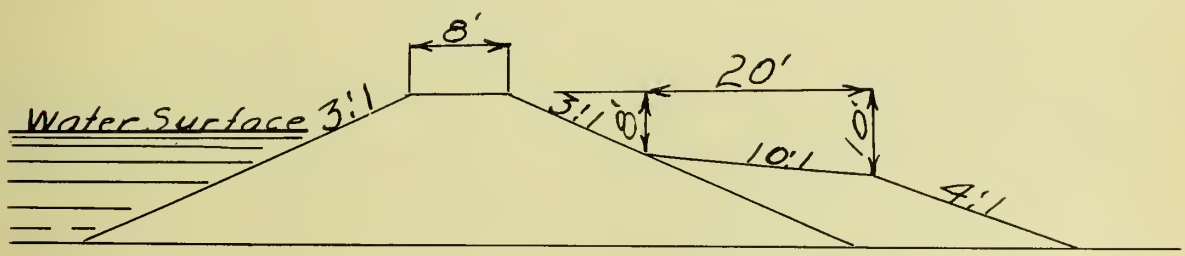
Section Near End of East Jetty

Fig. 5

CHAPTER 2

THE LEVEES.

The levees of the Mississippi are simply earthen ramparts which are built of the material to be found at hand, which may be either sand, loam or clay. Clay is the most satisfactory of the three but is seldom available. Experience has demonstrated that a levee, to have permanent wearing ability, should have an eight-foot crown and side slopes of three to one in loam or clay. If it exceeds ten feet in height it is reinforced on the land side by a bench or banquette eight or ten feet wide, as shown in Fig. 6 . The banquette starts from four to eight feet below the crown of the levee and slopes away three to one, or five to one. Levees made of sand are often sloped five to one on both sides. This slope was used in the Lake Bolivar Levee at the head of the Yazoo Basin, which gave a base width of more than two hundred and fifty feet in a seventy-five-foot levee.



Standard Levee Section

Fig. 6

When a levee is to be built, the line which it is to follow is selected as a compromise between the theoretical and the practical. Theoretically a levee should exactly follow the top of the lower bank, but this is prohibited by the unstable nature of the bank except where revetment has been applied. Upon moving this line back, however, the interests of the land owners are brought into play, with the result that a line is chosen which will give reasonable safety without undue encroachment upon the farm land.

The contractor who does the construction work is placed under a number of restrictions. He forfeits a heavy bond if he leaves a piece of wood or other foreign matter in the wall, makes a borrow pit more than four feet deep, or fails to purposly pack the earth. He must also make ample provision for shrinkage. Rigid systems of inspection are now employed which insure good workmanship.

The first levees were built for the protection of the property along the river, but later some were constructed for the purpose of reclaiming the swamp lands in the so-called "basins", along the river. In order to understand this latter phase of the work it will be necessary to know something of the topography of the country in which it was done. A short distance below Cairo the Mississippi breaks through a spur of the Ozark Mountains and enters a region entirely different from that traversed by the upper stream. Between Cape Girardeau and the city of Commerce, Missouri, the river seems trapped in a cul-de-sac, the bordering cliffs crossing directly over its course. Below Commerce, the bordering hills are about forty miles apart, and through this valley the river takes its tortuous course. From the west side at Commerce it

crosses by a long and crooked diagonal to the easterly bluffs at Columbus, Kentucky. It follows then with more or less regularity to Memphis, and then it moves in an opposite diagonal back to the west side at Helena, Arkansas. It thus has left between itself and the hills an irregular tract, pointed at both ends, forty miles wide in the middle, and containing about six thousand square miles. This region is generally known as the St. Francis Basin and a similar formation directly below it is known as the Yazoo Delta. These swamps are about forty feet above low water at the river side, and slope backward towards the hills and are drained by gently sloping streams which enter the deeper Mississippi at their lower borders. It was here that the work of reclamation took place By protecting these large areas from the floods pouring over the banks or entering from the lower end, the Government opened a large amount of rich land to cultivation.

The first levee construction of which we have any record was carried on at New Orleans in 1817. The finished levee was eighteen feet wide and about one mile long. It extended along one of the streets and was used as a roadway. At about the time of its completion, or probably before, the planters along the river began to construct small and poorly constructed levees along their river frontage. In 1850, the Government gave the river states all the unsold swamp and overflow lands within their borders to provide a fund for the construction of levees. This greatly stimulated interest in levee building and at the out-break of the Civil War a fairly complete but rather inadequate system extended from Cairo to New Orleans. During the war, however, this system fell into disrepair and at the close of the war neither the planters

nor the Southern states were in any condition to carry on the work. The work progressed very slowly and many of the gaps were still unfilled when the flood of 1874 came and washed out much that had been built. This stimulated interest and the levees were reconstructed only to be destroyed again in 1882.

In June 1879, Congress created a body known as the Mississippi River Commission, whose duty was to carry on the work of improving the river for the needs of commerce, and for the prevention of floods, in so far as they effected the commercial usefulness of the river. No funds supplied by the government were to be used in protecting private property. In 1882, the first appropriation was made for levees by the Commission. By the act of September, 19, 1890 the general repair and construction of the levees was authorized without restrictions, and since then this work has formed one of the most important items in the operation of the Commission. Up to February, 1904, $17,500,000 had been spent by the government and $40,000,000 by the municipalities. By the acts of 1904 and 1905, $2,000,000 were appropriated annually for river improvements, one half of which was to be spent for levees. In April 1912, an unprecedented flood caused considerable damage at Cairo and below, and Congress voted an additional $1,500,000 for the immediate repair of the levees. At present there are more than fifteen hundred miles of levees completed, which is 72% of the number of miles needed for a perfect system. The present levees are from two to four feet above the guage readings of the highest floods, and as the system approaches completion, they are being made stronger and safer.

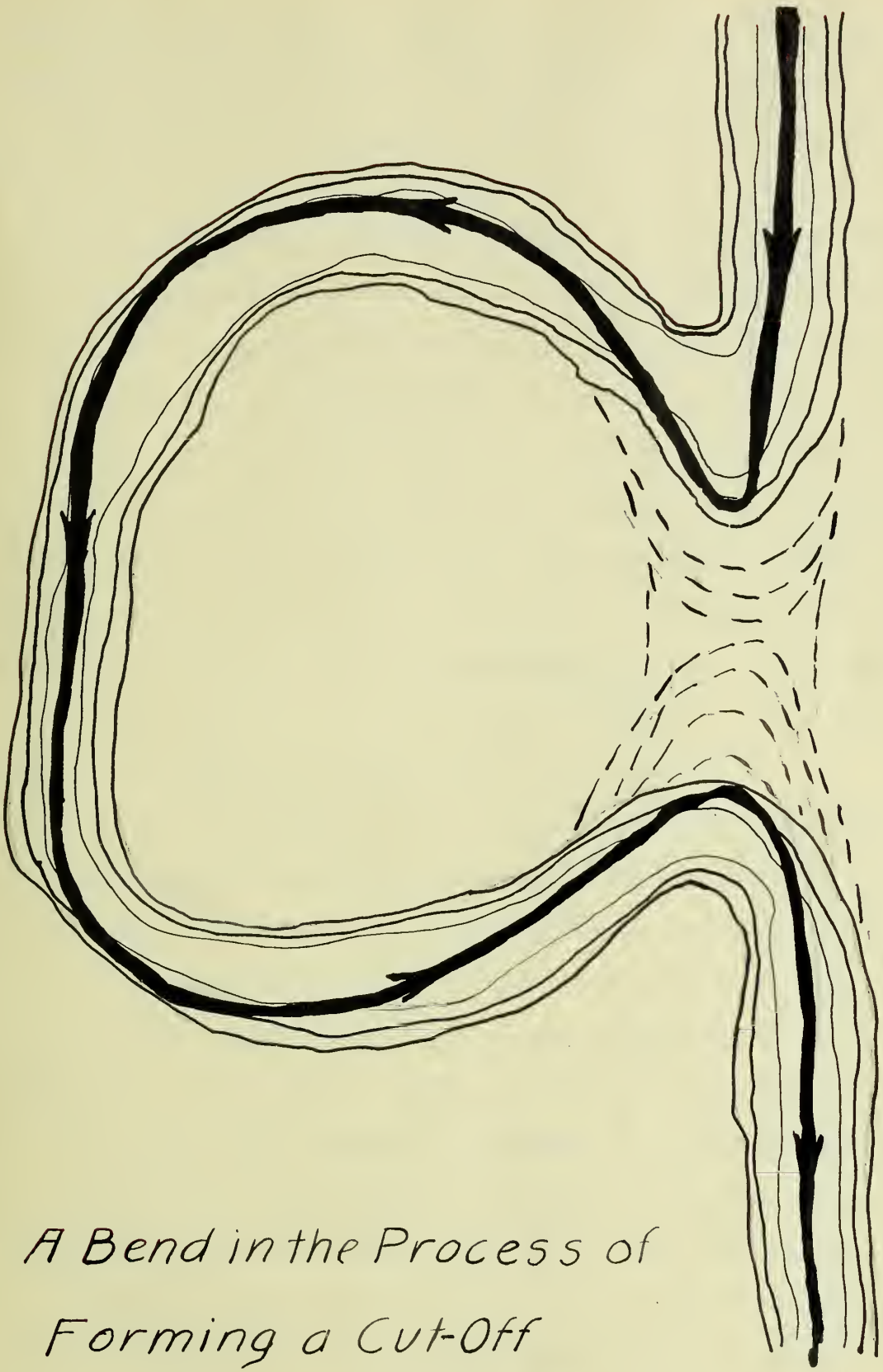
REVETMENT

It is difficult, if not impossible, for any person who has not studied the River in all of its manifold phases to appreciate the intricacy of the problems it presents, or the magitude of the operations that are necessary to maintain a channel along its tortuous course. It is hard to believe that a great stream like the Mississippi is so changeable and unstable that it shifts its channel from day to day, rendering the passage of boats hazardous and often times impossible; but such is the case, and it is for the prevention of these evils that the Mississippi River Commission was appointed. Owing to the fact that the river had made its own bed, we find the bed practically adapted to the stream which flows through it, and the two are so delicately balanced that the slightest interference is likely to produce great changes. The great number of curves and bends are necessary to reduce the velocity so that it would not scour out the present bed. The distance overland from Cairo to the Gulf is six hundred miles, and by river it is ten hundred and eighty. A fall of between 270 and 320 feet in the 1080 miles gives a velocity varying from 3 to 6 feet per second, and this is about the greatest that the channel can stand and maintain anything approaching its present form.

The present shifting of the channel is due almost entirely to the cutting back of the banks on the bends, which prevails continually on the lower Mississippi except in those places where the engineers have taken steps to prevent it. The main cur-

rent sweeps swiftly around the outside of a bend, and crosses with less speed from the foot of one to the head of the next, each bend being aimed in the direction opposite from that next above it. These bends often remain staple for years; and as often continue caving year after year, gradually reaching back until the river has so lengthened the slope in them that it is no longer able to erode the banks. In this process of retreat it not unfrequently happens that the bends, which are never contiguous but are separated by at least one reverse bend, approach each other, back to back, until either a flood pouring over the bank or the caving of the last obstruction wall makes an opening and creates a new channel, leaving only a sluggish current in the old one. A bend in the process of forming a cut-off is shown in Fig. 7 . Owing to the fact that the distance around these bends is from eight to twenty miles and that the fall is six or eight feet, this sudden shortening produces a very high velocity that causes the river to cut and tear down its banks for miles, rendering navigation either impossible or extremely hazardous. This will last for several years which is the time usually required for the stream to bring the channel to its original length. In order to prevent cut-offs and to protect the land and the levees which are built upon it, the process known as "bank revetment" is employed. This process consists of protecting the bank below water with a continuous mattress woven with brush and galvanized wire.

Before 1879 when Congress appointed the Mississippi River Commission, the government works carried out on the river were



A Bend in the Process of Forming a Cut-Off

Fig. 7

not revetment works proper. These works were done to correct and rectify the channel and to close chutes, and consisted of piles, dykes and retaining walls. Their policy was then to force all the water of the river into the main channel.

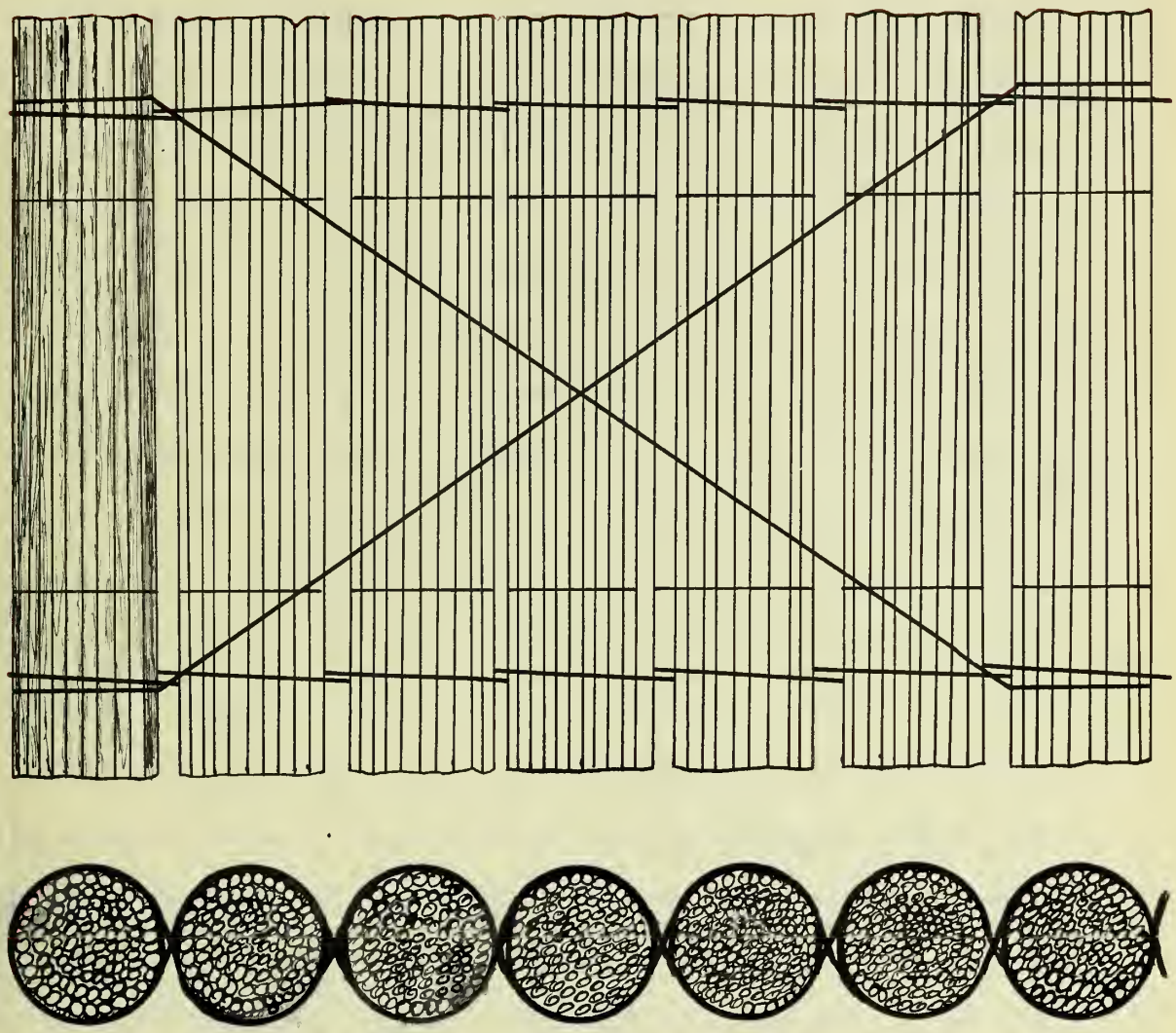
The first continuous work was done in 1878 and was intended to protect the banks under low water. The revetment consisted of mattresses one hundred and fifty feet by fifty feet which were built on ways erected on barges. Each mattress consisted of a crib made of poles six inches in diameter at the butt and eight feet apart secured by wires and strips to cross-stringers. All intersections were provided with hickory pins one inch in diameter and three feet long. The body of the mattress was very much the same as that used by Captain Eads in the construction of the jetties, and the top was formed by a second crib. The mattresses cost $18 per linear foot when sunk.

In 1880 it was found that the stone above the mattresses needed protection. Accordingly the banks were graded to an angle of forty five degrees and eight-inch mattresses were laid on them and secured by piles. It was found that the crib mattresses were not flexible enough to adjust thenselves to the contour of the river and in 1881 the process was greatly modified. The cribs were replaced by stripes of wire netting fastened together by wires running through the mattress. Longitudinal poles were placed eight feet apart under the netting to help in launching, and on top cross-rows of piles were wired, forming pockets which prevented the stone from rolling off during sinking. The slope covering consisted of rip-rap anchored

by dead-men. The hydraulic jet was first used in revetment work to level down the slopes above this form of mattress,

From 1883 to 1893 this method was steadily improved; but in the latter year its use was discontinued, owing to the fact that the mattresses still failed to have the proper amount of flexibility, and the fascine mattress now in use was adopted. The fascine mattress is made on floating ways fastened to a river barge. The barges are provided with a number of cable drums under each of the inclined ways, on which are wound and from which are played out as the construction of the mattress progresses the steel strands which constitutes the longitudunal strength of the mattress, and to which the fascines are woven. The drums are from eight to nine feet apart.

The first operation in the construction of the mattresses consists of building the "matt-head". This consists of a bundle two and one-half or three feet in diameter made of poles five to eight feet in length, which are bound together by wire strands, and form a beam of great flexibility. The "matt-head" is as long as the mattress and is moored to the bank below the barge. The wire strands from the drums are attached to it and a two foot layer of brush is woven in as shown in Fig. 8. In this operation the brush is made into fascines and bound with number twelve wire. These fascines are skidded into place against the "matt-head" and the weaving strand is passed over and under it and up between it and the "matt-head" crossing at the same time the bottom longitudinal strand. The strand is then drawn tight and stapled, and the next facine is put in as before. On top



A Fascine Mattress

Fig. 8

of the mattress thus constructed are placed rows of poles sixteen feet apart extending up and down stream. These are lashed to the fascines by number seven silecine bronze wire every five feet and at intermediate points by strong steel wire lashings. These poles are to prevent the stone from slipping off when the mattress is sunk on a deep slope; and also by being lashed to the body of the mattress by noncorosive wire to prevent the displacement of the brush when the steel wire and other corrosive connections are gone. These mattresses are sunk with stone in exactly the same way as those used in the jetties, and the slopes are paved with four to six inches of quarry spawls overlaid with six inches of stone extending up the bank to about the twenty-foot stage. The finished revetment costs thirty dollars per running foot.

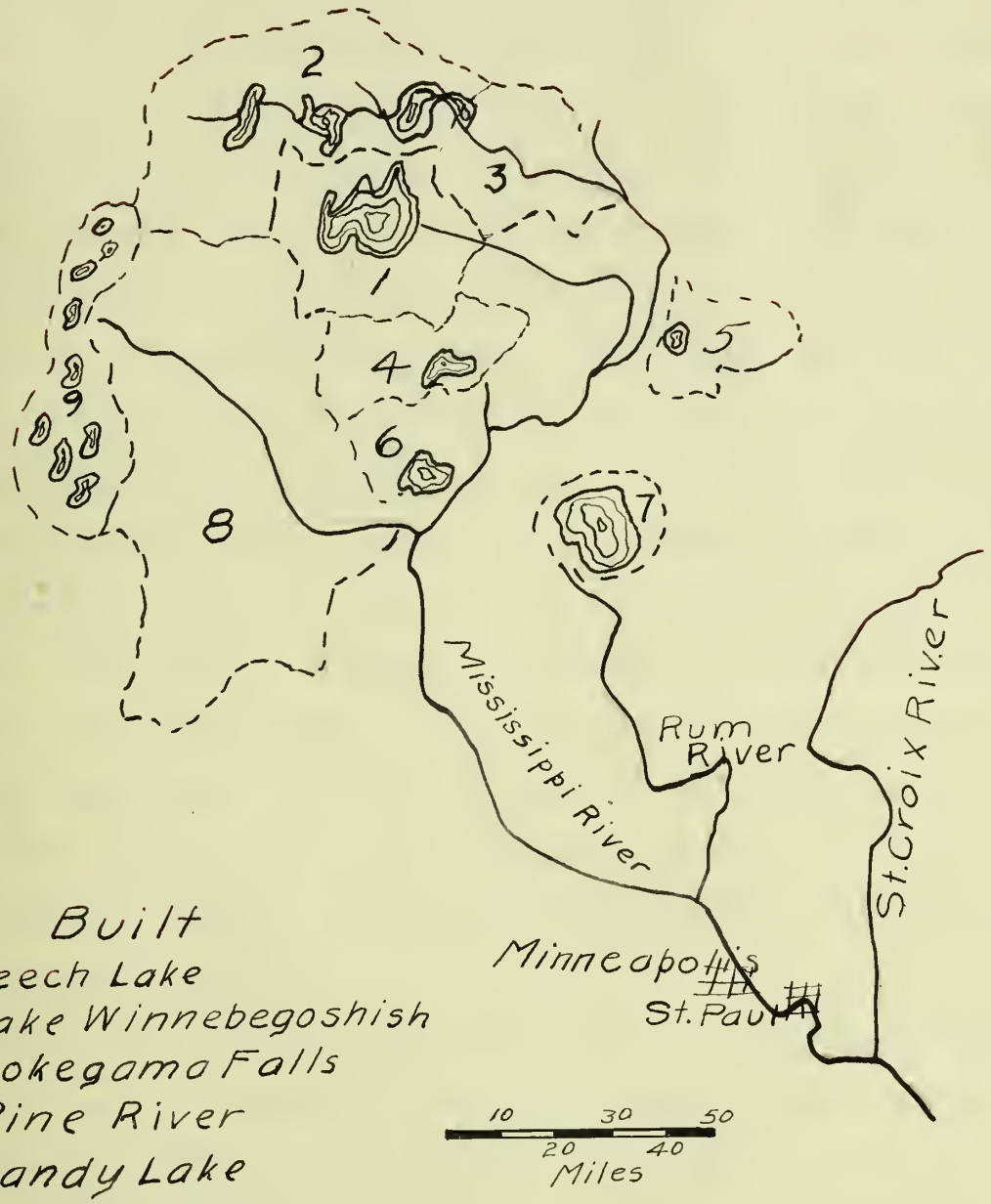
Revetment of this character is necessary on practically every bend if a perfect channel is to be assured. From the head of navigation on the Mississippi to the jetties of South Pass this must be the final recourse, and this means that something over eight hundred miles of revetment must be put in on the lower river before it can properly meet the demands of commerce and safety.

CHAPTER 4.

RESERVOIRS

The subject of reservoirs on the Mississippi has been discussed in a number of ways for a great many years. It was once thought practicable to attempt to build a system of reservoirs which would lighten the immense floods at the lower end of the river. More recently, however, this has been abandoned and a system of reservoirs has been built in Minnesota for the purpose of raising the water level below St. Paul.

Major Allen, of the United States Army Corps , is largely responsible for the existing system. He urged the adoption of the present plan, made the surveys and directed the work. From 1883 to 1886 five reservoirs were built by the government in a line extending northward from St. Paul for about two hundred miles at a total cost of $500,000.00. They were constructed by damming up the natural outlets of the lakes which cover that part of Minnesota, and are operated by impounding the waters in excess of the natural low water flow, when this excess is not needed by navigation, and by releasing it during the low water periods. They were constructed primarily for the benefit of commerce, but it is claimed that they aid in reducing the intensity of the floods and furnish water for irrigation. It is certain that they are absolutely necessary to the success of the proposed deep-waterway, but it is equally certain that their effect would be inappreciable if the channel were left in its natural condition. These reservoirs were built by simply damming up the natural outlets of small lakes which abound in this country. A sketch of the country is



Built

1. Leech Lake
2. Lake Winnebegoshish
3. Pokegama Falls
4. Pine River
5. Sandy Lake

Projected

6. Gull Lake
7. Mille Lacs
8. Crow Wing River
9. Otter Tail Lake

Reservoir Sites in Minnesota

Fig. 9

shown in Fig. 9. The dams were made of the earth found at hand and owing to the topography of the country, none of them could be constructed of sufficient height to be worthy of a detailed description. The side slopes are usually three to one, and the center of the dam is reinforced with a row of sheet piling. Around this sheet piling is a puddle wall six feet thick at the top with a side batter of one to six. The toe and heel of the dam are protected by sheet piling and a two-foot layer of clay is spread over all and covered with riprap. The sluice gates are twenty four in number and are constructed through a mass of cribbing. The spillway is one hundred and forty feet long and is built of plank. About fourteen years after the first of these dams were completed, the timber work in them had become so rotten that the dams were unsafe. A general deficiency act was approved July 7, 1898, which authorized the renewal of the Winnebegoshish and Leech Lake Dams. Their reconstruction was completed in 1900, all the timber parts being replaced by concrete or masonry. The government intends to replace the timber parts of the other dams in the near future.

The combined reservoir system will now discharge six thousand cubic feet per second for the ninety days between July 1st and October 1st when the flow in the river is not sufficient to maintain a depth of four feet below St. Paul. It is at present proposed to enlarge the system by dredging the existing sites and damming Gull Lake and Crow Wing River which will double the flow. The project of a six-foot channel from St. Paul to the mouth of the Missouri will be greatly influenced by the condition of these

reservoirs. It is not at all impossible to accomplish this, but it will require considerable improvement in the system and very careful handling after it is finished, as the reservoirs will be required to furnish 65% of the dry weather flow.

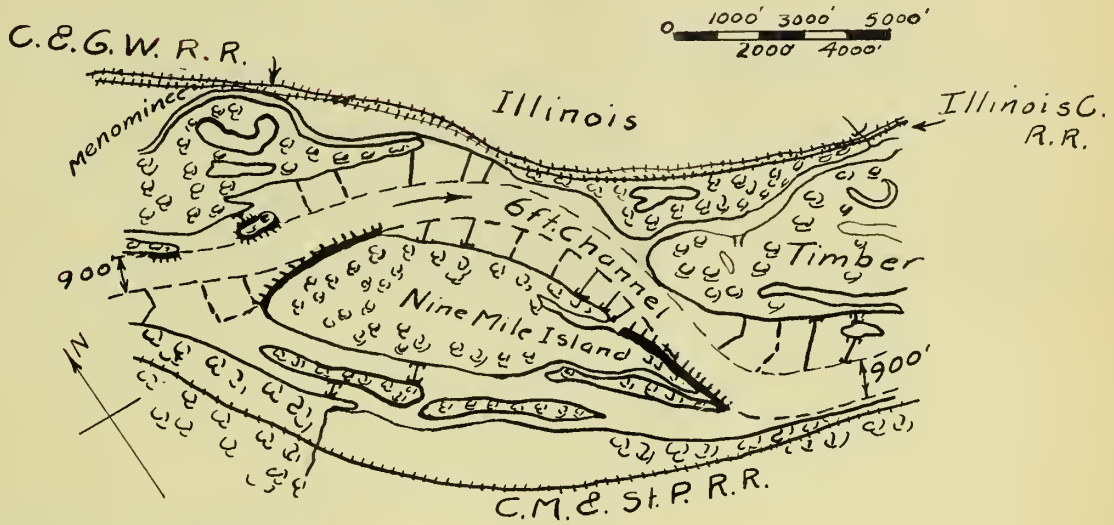
CHAPTER 5.

LOCKS AND DAMS

Owing to the fact that the states bordering on the Mississippi above the Missouri are exceedingly productive, it has long been the desire of the government engineers to construct a channel through the rapids which would offer safe passage for boats of moderate size. The largest rapids and falls have been improved by dams and locks or canals but much more remains to be done. In 1877 a series of three locks was installed in the rapids below Des Moines, Iowa, at a cost of six million dollars, and a little later a three-hundred-foot channel was chiseled out of the rocks at Rock Island, Illinois. Neither of these projects proved very successful.

At the present time an immense dam is being built at the foot of the Des Moines Rapids, which will render the old locks unnecessary. This dam is being built by a private corporation for power purposes. When finished the dam will be thirty feet high and nearly a mile long. It is being built of plain concrete and will have an average thickness of forty feet. The spillway will be four thousand two hundred and seventy-eight feet long and will be surmounted by one hundred and nineteen flood gates, thirty feet wide and eleven feet high, which will enable the operators to maintain a constant head of water nearly all the year round. Locks are being built on the Iowa side which will furnish a depth of eight feet without cost to the government. It is estimated that the dam will furnish a permanent stage of water for sixty miles up the river. The power company will probably be able to obtain

Typical Plan of Improvement-Upper River

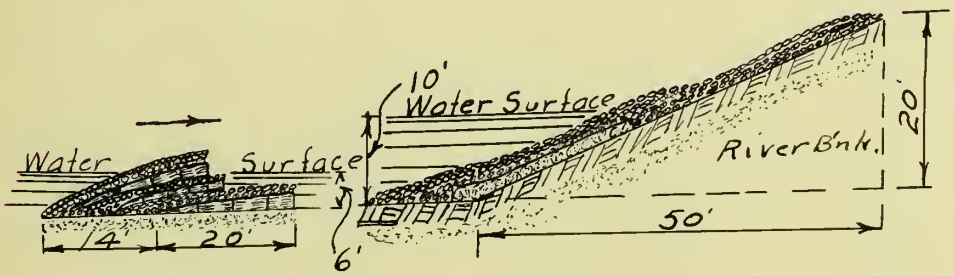


— — Dams to be built

– – – Shows 6 ft. Channel

——— Wing dams & Closing dams

▬▬▬ Bank revetment



Cross-section of Wing Dam

Cross-section of a Bank Revetment of Brush & Rock

Fig. 10

two hundred and twenty thousand kilowatts from the overfall.

The government has also done some important work in raising the water-level between the rapids. Practically the entire channel from Des Moines to St. Paul has been contracted by permanent banks similar to those shown in Fig.10. These banks are made of willow mattresses which resemble those used in the jetties. This channel contraction is vital to the deep-waterway project and with out it no available amount of reservoir discharge will be effective.

CHAPTER 6.

DREDGING

One of the earliest forms of improvement of which we have any record is dredging. Dredges were used in the passes as early as 1837, and in 1857 a well organized effort was made to deepen the channel by dredging. This form of improvement continued until the completion of the jetties in 1878, after which it was discontinued there for several years, but was used to some extent above New Orleans. In 1893 and 1895 more dredges were built and in 1904 ten new dredges were added to the fleet and are now in constant use.

The dredge now used is of the hydraulic type. Immense centrifugal pumps mounted on barges suck in the mud and water and discharge it either into tanks or into long pipes which carry it to the shallow water near the shore. These dredges are very effective having a capacity of from eight hundred to sixteen hundred cubic yards per hour.

A dredged channel is only a makeshift at best, but it is often of great service. A large fleet of hydraulics now operate on the lower Mississippi, keeping the channel in the best possible condition. They are made ready after a flood and when the river begins to fall they are sent to the crossings in which trouble is anticipated. If soundings show that the channel is cutting out, probably no dredging is necessary, but if the river seems to be shoaling out too much and not forming any distinct channel, a cut about two hundred and fifty feet wide is made at once. If the crossing is well chosen the river will at once adopt the new chute,

but if it is unwisely chosen the river quickly fills it up and tries to break out elsewhere, and the engineer chooses a new line and begins again. In an average season from four to seven crossing have to be thus dredged between Cairo and New Orleans to maintain a regular channel nine to ten feet in depth. This requires an expenditure annually of four hundred thousand dollars.

CHAPTER 7.

CONCLUSION

As the primary purpose of this paper is to discuss the methods by which the channel has been and will be turned to commercial account, it appears suitable to close it with a short sketch of the rise and decline of river traffic, and an indication of some of the causes of the success and the failure therein.

In the earliest days, river traffic was carried on by drifting boats built of timber or rough lumber, most of which went down to New Orleans from the interior loaded with native produce, and were broken up and sold for wood at New Orleans. In addition, there were the "keel-boats", in model not unlike the standard barges seen to-day on European waters, which returned up stream under the impetus of sail, oar, and cordeling rope and occasionally of side-wheels turned by horse-power. As early as 1802 the steamboat began to be discussed on the river, and in that year one was built for a Mr. McKeever, who had secured a privilege from the Intendant at New Orleans. His boat was destroyed before being finished, however, and aside from a few experimental models of Fitch's plan on the Ohio, no steam vessel floated on the river until the building of the first Fulton steamboat in 1811, the New Orleans. The Fulton-Livingston Company secured from the Louisiana legislature a monopoly of steam traffic on the lower river, but the young pioneer, Henry M. Shreve, having designed a more able boat than theirs, attacked them in the courts and defeated them.

There-after, under the stimulating enthusiasm of Shreve, who made many inventions and gave them without patent to his countrymen, the Mississippi River steamboat advanced more rapidly toward perfection than any other similar craft in the world; so that in twenty years there were several hundred high-pressure steamboats plying the stream, carrying fabulous cargoes at high freight charges. They were all built after practically the same model, designed by Shreve, and like the antique packets to be seen on the river to-day. Their engines were for the time magnificent, using even at that time steam at 160 pounds pressure. But the boats themselves had many faults. Their immense radial wheels weakened their hulls by continuously pounding upon the water. Their hulls and light decks, built flimsily to save weight, were liable to destruction by fire, and burned so rapidly when the overheated boilers started combustion as to cause many terrible diasters. The light wooden hulls were easily penetrated by snags, wrecking the boat. And the channel from which eventually the Shreve snag-boat cleared most of the obstructions, was so irregular and so unreliable that the boats frequently ran aground and were either lost or delayed.

Nevertheless, some of these vessels were exceedingly fast, making twenty miles an hour at an early epoch; and so long as slave labor continued they were able to do business with fair economy. Several new developments, however, came to the river, simultaneously. The war ended slave labor and destroyed the prosperity of the South. It also made for many years an entire end to the river transportation, and caused the burning or sinking of hundreds of steam-boats and the impovishment of all those who depended upon steam naviga-

tion for a livelihood. At the same time a railroad for the first time paralleled the river and another cut across it, joining the western fields directly to the East.

During the continuance of the war it was necessary for the North to carry the grain of the new West to the seaboard ports and for distribution to the army. The exporting of this grain and the meat stores was essential in order to maintain foreign credit and to provide the expenses of the war. Every energy was turned towards the creation and improvment of the transcontinental lines; and inventive genius, fascinated by this problem of national safety and by the rich rewards for success, turned towards the improvment of the locomotive and to all parts of railway service. At the same time the Eastern harbors were being improved, deep steam vessels were supplanting the old wooden sailing ships, and the South was stagnated. Naturally, when the war closed, the river was unable to recover. There was no longer a fighting chance for it. It had at its mouth the impovished city of New Orleans, and a channel through which only old clippers drawing at best only sixteen feet of water could pass. In its export rates and facilities it could not compare with any of the Eastern ports. Its terminals had no facilities for handling freight. Slave labor was abolished, but no substitute for it except the free darky had been devised. The steamboat of Shreve, with no new improvments of value, continued to be the river type. It could compete with the railroads of its own time; but in a channel uncertain and dreaded it could not compete with the quicker, safer, and in the end not more expensive

railway of the post-bellum days.

As a result, though the river traffic increased rapidly after the war until about 1871, and produced some famous vessels as the Robert E. Lee and the Natchex, it bacame evident that it was only a last burst before the death of the old style methods. The combination passenger and freight boat with many handicaps, could no longer hold its own. An endeavor was made to substitute freight-barges carrying grain from St. Louis to New Orleans, and after the opening of the Mississippi's mouth by Eads and the erection of elevators at New Orleans this traffic considerably increased. St. Louis arrived at a freight momement by water of more than a million tons a year, not including her local transfer service.

Still there remained several handicaps to the service, some of which were and some were not perceived by those interested. In order that the river traffic may compete with rail, it must have the same facilities for cheap transfer, for quick handling, and for safety as the railway has. On the Mississippi there was not from end to end any facilities for loading and unloading packages of freight except the brawny negroes, who still "toted" by hand even the heaviest packages. The boats were still the old sort, with no possibility of receiving or delivering cargo except by hand or trucks. Even the barges which carried grain from St. Louis were roofed over, so that while grain might be piped into their holds, the return cargo must be put aboard by hand. There were no proper railway terminals at the levees, and freight which went to and from the river even at important terminal cities paid as high as $1 or even $2 for local teaming charges.

There were no harbors along the stream, and the packets employed the ancient method of picking up and delivering freight at every plantation, much as if the trains from New Orleans to Chicago should stop for cotton bales at every plantation they passed.

Successful traffic on the river, requires just as it does on a rail road, a complete separation of passenger and freight service. Passengers must be handled on swift, comfortable, through boats. Freight requires more time, and a different type of vessel. Nowhere on the river were these two classes of boats provided, except in the case of the St. Louis grain and the Pittsburg coal barges. So St. Louis handicapped by its own inefficiency saw its water-traffic drop back to a third of a million tons a year all of which is local freight for small towns below or for plantations. Only a single movement of freight remained prosperous on the river, that of the coal upon the Ohio. The movement of this in immense fleets- sometimes 60,000 tons at a time- on the high water, downstream, is one of the largest and cheapest freight movements in the world, being carried out at a cost less than the cheapest ocean freightage. The empty barges are pushed upstream for reloading, often with small barges of return freight, and the transfers are accomplished more quickly and economically than by rail. Yet even this is done in the old-fashioned way; and there is no doubt that the present charges would be cut in half by study and the use of modern methods.

It is commonly said now that the railroads killed the through traffic of the Mississippi. This is far from the truth.

The traffic became moribund from stagnation, by the failure of American men to apply to it the same inventive genius and the same free use of capital which they applied to the railway service. But it was finally wounded almost fatally by the uncertainty of the channels and the inefficiency of the terminal service; two things which were tolerable as soon as the railways did away with them. At any time within the last twenty years the Mississippi might have been benefited, and the traffic revived by the organization of a competent corporation large enough to systematize and develop the trade, wise enough to provide modern machinery in all departments, and rich enough to weather the first months of proving to the shipping interests their sufficiency.

Now, however, we have arrived at a new epoch. The turning of traffic toward the Gulf has forced the railways into new efficiency. The opening of the Panama Canal will more than double our trade in that direction. The present certainty of our channels, deeper than the best in Europe, makes traffic easy. There only remains the proper transhipping terminal apparatus and the proper boats to be provided, and these channels of the Mississippi will become the greatest carriers and the greatest arteries of our internal system. They will not interfere with the railroads. There is and always will be freight enough for both. A great mass of imports for the valley instead of being hauled overland from New York ought to and will be brought up the Mississippi to Cairo or to St. Louis for distribution. The export product of the valley ought to, and will, go to New Orleans for its sea outlet. And from St. Louis as a center, to Pittsburg

to Omaha, to St. Paul, and to Chicago will go the interchanging goods of the heart of the continent by water; increasing the prosperity of the whole region, and increasing at the same time, as experience has shown to be inevitable, the traffic both of the railways which parallel them and of those which, crossing them, distribute to the hinterland the river-borne goods.

In another decade not three hundred thousand, but more than three million tons of freight ought to move in and out from the central point each year. When the Chicago route shall have been open two years, it should be carrying as much more. And when the Pittsburg-Lake route is open, and the Ohio canalization sufficiently completed, and the Missouri once more fairly in control, there should be almost an equal traffic going from east to west and west to east, by Erie canal barges or by river barges, from the eastern sea-board down and up the Ohio around by Cairo to St. Louis, and so by the Missouri for distribution from and collection in the great depots at Kansas City, Omaha, and Sioux City.

Then the Mississippi will have come into its own; and then all America, feeling the increase of prosperity with this cheap and efficient internal circulation, will benefit from the belated and irregular expenditures we have made upon the remaking of the Mississippi.

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